DECLARATION

I, Yutaka Horii, c/o Fukami Patent Office, of Mitsui Sumitomo Bank Minamimorimachi Building, 1-29, Minamimorimachi 2-chome, Kita-ku, Osaka-shi, Osaka, Japan, declare:

that I know well both the Japanese and English languages;

that to the best of my knowledge and belief the English translation attached hereto is a true and correct translation of Japanese Patent Applications No. 2000-059877, filed on March 6, 2000;

that all statements made of my own knowledge are true;

that all statements made on information and belief are believed to be true; and

that the statements are made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 USC 1001.

Dated: July 7, 2005

Yutaka Horii

日本国特許庁
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This is to certify that the annexed is a true copy of the following application as filed with this Office.

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[Title of the Invention] OPTICAL DISK DEVICE

[Claims]

[Claim 1] An optical-disk device for reproduction of an optical disk having information recorded thereon by pits comprising:

a light-receiving device for receiving reflected light of a light beam which is directed to pits;

means for detecting the deviation of the light beam with respect to pit arrays and creating a tracking servo signal which is a signal component of the deviation;

means for detecting the depths of the pits; and

means for performing control of the output of said tracking servo signal, on the basis of a signal indicating said pit depths.

[Claim 2] The optical-disk device according to Claim 1, wherein said means for performing control of the output of the tracking servo signal performs control, on the basis of the signal indicating the depths of said pits, such that only tracking servo signals from pits having a predetermined depth are output.

[Claim 3] The optical-disk device according to Claim 1 or 2, wherein said means for extracting the depths of pits performs detection, on the basis of the polarity of a signal which corresponds to the difference of the intensity distribution of the reflected light of the light beam directed to the pits, along the tangential direction of the pit arrays.

[Claim 4] The optical-disk device according to Claim 3, further comprising means for detecting a signal indicating the presence or absence of pits on the disk on the basis of the light quantity of reflected light of the light beam directed to pits,

wherein said means for detecting the depths of pits performs detection on the basis of said signal indicating the presence or absence of pits and the polarity of a signal which corresponds to the difference of the intensity distribution of the reflected light of the light beam directed to the pits, along the tangential direction of the pit arrays.

[Claim 5] The optical-disk device according to any one of Claims 1 to 4, wherein said tracking servo signal is created from the reflected light of the light beam directed to pits, in accordance with the Differential Phase Detection method.

[Claim 6] The optical-disk device according to any one of Claims 1 to 4, wherein said tracking servo signal is created on the basis of the difference of the intensity distribution of the reflected light of the light beam directed to pits, along the radial direction of said optical disk.

[Claim 7] The optical-disk device according to any one of Claims 1 to 6, wherein said light receiving device is configured to detect intensity distributions along the directions which are substantially parallel with the tangential direction of said pit arrays and the radial direction of the optical

disk.

[Claim 8] The optical-disk device according to Claim 7, wherein said light receiving device is configured to have substantially "a crisscross-divided square" shape.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to tracking servo for optical disk devices used with an optical disk having information pre-recorded with convex and concave shaped pits, over the entire or a portion of the recording surface thereof.

[0002]

[Prior Art]

For optical-disk reproducing apparatuses for reproducing information from an optical disk having information pre-recorded on the disk surface thereof with convex and concave shaped pits, there have been suggested various types of tracking servo techniques for positioning a light beam on the pit arrays, as disclosed in Japanese Patent Laying-Open No. 58-1501145, for example.

[0003]

Fig. 6 is a block diagram of tracking servo in accordance with the Differential Phase (Differential Time) Detection method, wherein the block diagram is illustrated by redrawing the structure disclosed in Fig. 3 and Fig.

4 in the aforementioned Japanese Patent Laying-Open No. 58-150145.

[0004]

The differential phase (differential time) detection method is a method which receives a light beam reflected by an optical disk with a photo detector having four devices along the radial direction and the tangential direction of the optical disk, determines the sum signals of outputs of diagonally-placed devices of the photo detector, and detects the phase difference (time difference) between the sum signals for performing tracking.

[0005]

In Fig. 6, the reflected light from the disk is condensed and directed to a photo detector 2, and the respective portions output signals corresponding to the quantities of incident lights. Adding amplifiers 3-1 and 3-2 determine the sum signals of outputs from portions a and c and b and d which are placed diagonally with each other and output them to comparators (comparing circuits) 5-1 and 5-2. The comparators 5-1 and 5-2 make a comparison between the output signals from the adding amplifiers 3-1 and 3-2 and reference signals +Ref1 and +Ref2 and output binarized signals resulted from the comparisons.

[0006]

Since the reflected light beam has been diffracted by the pits, the intensity distribution of the reflected light on the photo detector is varied with time, depending on the positional relationship between the light beam and the individual pits.

[0007]

For example, when the light beam follows the pit arrays just

thereabove, the sum signals of outputs from the diagonally-positioned devices (a+c) and (b+d) of the photo detector above the pits exhibit the same change, which causes the output signals from the comparators 5-1 and 5-2 to exhibit the same change with the same timing. When the light beam follows the pit arrays at a position deviated from the position just thereabove, one of the sum signals of outputs from the aforementioned (a+c) and (b+d) is varied more early than the other, depending on the direction of the deviation, by the phase difference (time difference) corresponding to the amount of the deviation.

[0008]

Therefore, by using a phase comparing circuit 7 to detect the phase difference (time difference) between the output signals from the comparators 5-1 and 5-2 and to output pulses corresponding to the aforementioned phase difference (time difference), then extracting only low-frequency components from the pulses with LPFs (low-pass filters) 8-1 and 8-2 and determining the difference therebetween with a differential circuit 9, it is possible to generate a tracking signal indicating the amount and the direction of the deviation of the light beam relative to the pit arrays.

[0009]

As another exemplary technique for generating tracking servo signals, there is a push-pull method. The push-pull method is a method which determines the light-quantity difference between the inner side and the outer side of the reflected light beam, which is divided along the tangential direction, and utilizes it as a tracking signal, and Fig. 7 represents an exemplary block diagram for generating tracking servo signals

in accordance with the push-pull method.

[0010]

When a light beam is directed to the pit arrays, the reflected light has been subjected to diffraction with the pits depending on the positional relationship between the light beam and the pit arrays, and the push-pull method divides the reflected light into two parts at the inner side and the outer side of the optical disk, detects them and creates a tracking servo signal on the basis of the average light intensity.

[0011]

Referring to Fig. 7, while the reflected light is condensed onto a four-divided photo detector, similarly to the aforementioned differential phase (differential time) detection method, the adding circuits 3-1 and 3-2 add output signals from the devices positioned at the inner side and the outer side, rather than the devices positioned diagonally in the photo detector, and output the result of the addition to a differential circuit 17.

[0012]

The differential circuit 17 outputs the result of determination of the difference between the two signals from these adding circuit 3-1 and 3-2 to an LPF 18, which eliminates high-frequency components of the respective pits from the result of the difference determination for extracting low-frequency components, namely signal components corresponding to a substantially-averaged deviation of the light beam relative to the pit arrays, as a tracking servo signal. This is the principle of the push-pull method.

[0013]

[Problems To Be Solved]

At present, there is generally utilized, for optical disks, pit (mark) length recording which provides information to the presence or absence of pits or marks and also to the lengths. If information is also provided to the depths of pits, recording of information having greater capacities can be expected. This has been already proposed by the inventors as JP-A No. 11-184604. This technique enables adding new information by utilizing the fact that diffraction patterns resulted from interference of light by convex and concave pits are varied depending on the depths of pits.

[0014]

Fig. 8 is a schematic diagram illustrating the principle of reproduction of information recorded by the pits depth. In assuming that the wavelength of light is λ and the refractive index of the optical-disk substrate is n, pits 31 are relatively shallow pits having a depth of about $(\lambda/6n)$, which is smaller than $(\lambda/4n)$ and hatched pits 32 are relatively deep pits having a depth of about $(\lambda/3n)$, which is greater than $(\lambda/4n)$. When a light beam is scanned over the pit arrays in the direction of an arrow represented in the figure, the total-sum signal (a) of light quantities of incident lights to the photo detector does not exhibit significant difference between when the light beam exists on the pits 31 and when it exists on the pits 32. Namely, the information represented by the total-sum signal of light quantities is not significantly varied depending on the pit depth. Since stable reproduction of information is possible when the light quantity is significantly varied depending on the presence or absence of pits, it is desirable that the total-sum signal of light quantities does not vary depending on the pit depth and no information is given to the pit depth.

[0015]

However, in paying attentions to the signal created by dividing reflected light into forward and backward half portions along the direction of light-beam propagation and determining the light-quantity difference therebetween, namely the tangential push-pull signal (b), the pulse-shaped signal generated when the light beam is reaching or separating from a pit is reversed in the polarity due to the difference in the light diffraction pattern caused by the pit depths. This is a phenomenon completely independent from the change in the total-sum signal, which depends on the presence or absence of pits.

[0016]

Accordingly, by detecting the polarity of the tangential push-pull signal, it is possible to add new information to the pit depth, as well as to the presence/absence and the lengths of pits. This is the outline of the aforementioned JP-A No. 11-184604 which was filed by the inventors.

[0017]

However, the reverse of the polarity of the tangential push-pull signal depending on the pit depth means that the diffraction pattern of the reflected light changes depending on the pit depth. Therefore, with the Differential Phase Detection method and the push pull-method which utilize the intensity distribution of reflected light caused by diffraction patterns, the tracking signal may be reversed in the polarity between for deep pits and for shallow pits, which prevents normal tracking servo control with conventional methods such as the differential phase detection method and the push-pull method.

[0018]

The present invention provides a technique which enables normally performing tracking servo control for optical disks having pits with different depths as previously described.

[0019]

[Means for Solving the Problems]

According to a first invention of the present application, an optical-disk device for reproduction of an optical disk having information recorded thereon by pits includes a light-receiving device for receiving reflected light of a light beam which is directed to pits, means for detecting the deviation of the light beam with respect to pit arrays and creating a tracking servo signal which is a signal component of the deviation, means for detecting the depths of the pits, and means for performing control of the output of said tracking servo signal, on the basis of a signal indicating said pit depths, in order to solve the aforementioned problems.

[0020]

According to a second invention of the present application, the aforementioned means for performing control of the output of the tracking servo signal performs control, on the basis of the signal indicating the depths of said pits, such that only tracking servo signals from pits having a predetermined depth are output, in order to solve the aforementioned problems.

[0021]

According to a third invention of the present application, the aforementioned means for extracting the depths of pits performs detection,

on the basis of the polarity of a signal which corresponds to the difference of the intensity distribution of the reflected light of the light beam directed to the pits, along the tangential direction of the pit arrays, in order to solve the aforementioned problems.

[0022]

According to a fourth invention of the present application, there is further provided moans for detecting a signal indicating the presence or absence of pits on the disk on the basis of the light quantity of reflected light of the light beam directed to pits, wherein said means for detecting the depths of pits performs detection on the basis of said signal indicating the presence or absence of pits and tho polarity of a signal which corresponds to the difference of the intensity distribution of the reflected light of the light beam directed to the pits, along the tangential direction of the pit arrays, in order to solve the aforementioned problems.

[0023]

According to a fifth invention of the present application, wherein the aforementioned tracking servo signal is created from the reflected light of the light beam directed to pits, in accordance with the Differential Phase Detection method, in order to solve the aforementioned problems.

[0024]

According to a sixth invention of the present application, wherein the aforementioned tracking servo signal is created on the basis of the difference of the intensity distribution of the reflected light of the light beam directed to pits, along the radial direction of said optical disk, in order to solve the aforementioned problems.

[0025]

According to a seventh invention of the present application, wherein the aforementioned light receiving device is configured to detect intensity distributions along the directions which are substantially parallel with the tangential direction of said pit arrays and the radial direction of the optical disk, in order to solve the aforementioned problems.

[0026]

According to a eighth invention of the present application, wherein the aforementioned light receiving device is configured to have substantially "a crisscross-divided square" shape, in order to solve the aforementioned problems.

[0027]

[Embodiments of the Present Invention]

Embodiments of the present invention will be described using Figs. 1 to 5. First, a first embodiment will be described. Fig. 1 is a block diagram of main portions, in the case where the present invention is applied to an optical disk device using a so-called Differential Phase Detection (DPD) method for creating tracking signals.

[0028]

Reflected light from an optical disk is condensed and incident to a photo detector 2 and the photo detector 2 outputs signals proportional to respective incident-light quantities. The photo detector is preferably arranged to divide reflected light along two directions which are the direction of the light-beam propagation, namely the tangential direction of pit arrays formed on the optical disk, and the radial direction of the optical

disk.

[0029]

Adding circuits 3-1 and 3-2 output signals of the sums of outputs from the diagonally-positioned portions a and c and b and d of the photo detector 2 while adding circuits 3-3 and 3-4 output signals of the sum of outputs from the a and d toward the direction of light-beam propagation and signals of the sum of outputs from the b and c toward the direction opposite to the direction of light-beam propagation.

[0030]

Further, an adding circuit 4 determines and outputs the total sum of outputs from the photo detector 2. Comparators 5-1 and 5-2 compare the outputs from the adding circuits 3-1, 3-2 with predetermined reference voltages +Ref1 and +Ref2, respectively, and input binarized signals, which are the results of the comparison, to a phase comparing circuit 7.

[0031]

The phase comparator circuit 7 makes a comparison between an R input and a V input and outputs a pulse having a width corresponding to the phase difference therebetween depending on which of them advances in phase. For example, in this case, a pulse with a width corresponding to the amount of delay is output from an U output when the V input is delayed from the R input and output from a D output when the V input advances.

[0032]

LFPs 8-1 and 8-2 extract only low-frequency components from the U output signal and the D output signal from the phase comparator circuit 7 and input them to a differential circuit 9 and the differential circuit 9

outputs, as tracking signals, the difference between the outputs from the LFPs 8-1 and 8-2, namely the difference between the low-frequency components of the outputs from the phase comparator circuit 7.

[0033]

On the other hand, a comparator (comparing circuit) 10 compares the output from the adding circuit 4 which determines the total sum of the output signals from the photo detector 2 with a roforence voltage +Ref4 and inputs, to an edge detecting circuit 11, a binarized signal which is the result thereof, namely a signal indicating whether the reflected-light quantity is small or large due to the absence or presence of pits. Out of the rising and falling edges of the output signal from the comparer 10, the edge detecting circuit 11 outputs a pulse at the rising edge which corresponds to the transition from no-pit to pit in Fig. 1.

[0034]

The outputs from the adding circuits 3-3 and 3-4, which determine the outputs from the devices positioned forward and backward along the direction of light-beam propagation, are input to a differential circuit 12. Since the output of the differential circuit 2 is a signal indicating the intensity-distribution difference of reflected light in the tangential direction of pit arrays, it is called a tangential push-pull signal and is input to comparators (comparing circuits) 13-1 and 13-2. The comparator 13-1 compares the tangential push-pull signal with a predetermined reference voltage +Ref3 and outputs "H" when the tangential push-pull signal is greater than +Ref3 while the comparator 13-2 compares the tangential push-pull signal with a predetermined reference voltage -Ref3 and outputs

"H" when the tangential push-pull signal is smaller than -Ref3.

[0035]

The outputs of the comparators 13-1 and 13-2 are connected to one of the input terminals of AND gates (mask circuits) 14-1 and 14-2, respectively, and the other input terminals of the AND gates 14-1 and 14-2 are both connected to the output of the edge detecting circuit 11.

[0036]

Consequently, the AND gates 14-1 and 14-2 output pulses depending on whether the outputs from the comparators 13-1 and 13-2 are "H", at the time that a pulse is output from the output of the edge detecting circuit 11.

[0037]

From another viewpoint, it can be said that these AND gates 14-1 and 14-2 check and output the binarized tangential push-pull signal which is the output from the comparators 13-1 and 13-2, at the time of transition of the binarized reflected-light quantity signal which is the output from the edge detecting circuit 11.

[0038]

Also, it can be said that, even when the comparators 13-1 and 13-2 generate outputs at other timings than the specific timing of generation of a pulse from the edge detecting circuit 11, the AND gates 14-1 and 14-2 function to mask them for preventing them from being output.

[0039]

The outputs of the AND gates 14-1 and 14-2 are connected to clock inputs of FF circuits 15-1 and 15-2. Further, their D inputs are connected to an "H" level and, therefore, the FF circuits 15-1 and 15-2 are connected to

output "H" when a pulse is input to the clock inputs and output "L" when a pulse is input to the reset terminals.

[0040]

On the other hand, the reset terminal of the FF circuit 15-1 is connected to the output of a pulse-generating circuit 16-2 which generates a pulse at the rise of an output Q of the FF circuit 15-2 while the reset terminal of the FF circuit 15-2 is connected to the output of a pulse-generating circuit 16-1 which generates a pulse at the rise of an output Q of the FF circuit 15-1, and there is provided a structure in which, when an output Q of the aforementioned FF circuits 15-1 or 15-2 rises, namely when the AND gate 14-1 or 14-2 outputs a pulse to the FF circuit 15-1 or 15-2, the other FF circuit is reset.

[0041]

The output signals from the FF circuits 15-1 and 15-2 are input to an S/H-signal generating circuit 19. The S/H-signal generating circuit 19 selects and outputs one of the input signals on the basis of whether the signals to be currently reproduced are information of shallow pits or deep pits. An S/H circuit 20 samples (or through) or holds the output signal from the differential circuit 9 on the basis of the output from the S/H-signal generating circuit 19. Namely, even when there are pits of two different depths exist mixedly, the S/H-signal generating circuit 19 and the S/H circuit 20 enables outputting tracking servo signals only when the light beam exists on pits having the width to be reproduced, while on pits having the other depth the immediately preceding tracking servo signal is held, which enables performing stable tracking servo.

[0042]

Then, there will be described, using Fig. 2, the waveforms and the timings thereof at respective portions of Fig. 1, when a light beam follows the pit arrays of an optical disk having pits with different depths.

[0043]

In Fig. 2, 31 are relatively shallow pits while hatched 32 are relatively deep pits. When a light beam 1 follows them, the output signal (a) of the adding circuit 4 indicating the reflected-light quantity is varied between a large and small levels depending on the presence or absence of pits. The level is decreased as the light beam reaches pits and is increased as it separates therefrom.

[0044]

On the other hand, the tangential push-pull signal (b), which is the output of the differential circuit 12, represents the determined intensity-distribution difference of the reflected light beam along the tangential direction of the pit arrays as previously described, and therefore when the forward half portion and the backward half portion along the direction of the light-beam propagation are in different situations, more specifically when the light beam is reaching or separating from pit, at the time that it exists near the forward and backward edges of pits, pulse-shaped signals of opposite polarities are generated.

[0045]

The intensity distribution of the reflected light from pits is resulted from the influences of diffractions by pits on the light beam and, more specifically, in assuming that the used light (light beam) has a wavelength of

λ and the optical-disk substrate has a refractive index of n, the direction of diffraction is reversed at (λ/4n) as a boundary.

[0046]

Consequently, when there are formed shallow pits with a depth smaller than the aforementioned boundary (λ/4n) and deep pits with a depth greater than the aforementioned boundary (λ/4n), the polarity of the tangential push-pull signal is reversed when tho light beam reaches or separates from pits.

[0047]

Consequently, by observing the polarity of the tangential push-pull signal at the time point of change of the level of the output signal (a) from the adding circuit 4, which indicates the aforementioned reflected-light quantity, the pit depth can be determined and detected. By performing processes for extracting the tracking signal on the basis thereof, it is possible to perform correct tracking servo control, even when the polarity is reversed due to the difference in the pit depth. This is a basic concept of the present invention.

[0048]

Also, by detecting the depths of pits from the tangential push-pull signal, etc., and providing additional information to, for example, deep pits using the difference thereof, it is possible to increase the recording density or provide additional information. For such optical disks, the extraction of the polarity of the tracking servo signal according to the present invention is effective and enables correct following of tracking, thus enabling accurate reproduction of the aforementioned additional information, even when pits with different depths mixedly exist.

[0049]

In Fig. 2, the tangential push-pull signal (b) becomes positive when the light beam is reaching a shallow pit 31 and becomes negative when it is separating therefrom and, for a deep pit 32, the push-pull signal exhibits the opposite change. Off course, it goes without saying that even when their relationship is the opposite, it is possible to cope therewith easily by changing some connections in the circuit, etc.

[0050]

Returning to Fig. 2, the description of the operation will be continued. The comparator 10 binarizes the output signal (a) of the aforementioned adding circuit 4 with the reference voltage +Ref4, resulting in (c), which is changed in level between "H" and "L", depending on the presence or absence of pits, not on the depth thereof. Such level changes occur near the edges of pits and, in this case, the edge detecting circuit 11 outputs a pulse signal (d) at the fall of (C), namely at the time the light beam is reaching pits.

[0051]

On the other hand, the tangential push-pull signal (b) is compared with the different reference values +Ref 3 and –Ref3 by the comparators 13-1 and 13-2, respectively, and made to be binarzed signals represented as (e) and (f). The logical products of these binarized signals and the output (d) from the edge detecting circuit 11 are the outputs (g) and (h) of the AND gates 14-1 and 14-2. For a shallow pit, at the time point that the edge detecting circuit 11 generates an output pulse (d), the output of the comparator 13-1 becomes an "H" level, which causes the output (g) of the AND gate 14-1 to generate a pulse, thus causing the output Q of the FF

circuit 15-1 to become an "H" level. On the contrary, for a deep pit, at the time point that the edge detecting circuit 11 generates an output pulse (d), the output of the comparator 13-2 becomes an "H" level, which causes the output (g) of the AND gate 14-2 to generate a pulse, thus causing the output Q of the FF circuit 15-2 to become an "H" level.

[0052]

As previously described, the sample holding circuit 19 and the switch 20 generate tracking servo signals from only DPD signals having a polarity to be used for tracking.

[0053]

Further, in Fig. 1, for example, when the phase comparing circuit 7 itself includes two sets of circuits for detecting the phase difference between the R input and the V input, wherein one of them is for detecting the advance or delay of the V input with respect to the R input while the other is for detecting the advance or delay of the R input with respect to the V input, it is possible to directly switch the operation of the phase comparing circuit 7 using the outputs Q of the FF circuits 15-1 and 15-2, in order to cause only one of them to operate.

[0054]

Further, in Fig. 1, even when the AND gates 14-1 and 14-2 are eliminated and the output of the edge detecting circuit 11 is directly provided to the clock inputs of the FF circuits 15-1 and 15-2 while the D input of the FF circuit 15-1 is connected to the output of the comparator 13-1, not fixed at the "H" level and the D input of the FF circuit 15-2 is connected to the output of the comparator 13-2, not fixed at the "H" level, the same operation can be

achieved.

[0055]

Also, even when the edge detecting circuit 11 operates to output a pulse at the rise of an output of the comparator 10, not at the fall, or at both the rise and fall, it is possible to provido a structure for extracting the polarity of the tracking servo signal depending on the pit depth, similarly, by adding some modifications to the circuit.

[0056]

In the respective components according to the present embodiment, once the outputs of the respective devices of the photo-detector are binarized through the comparators, thereafter processes for the binarized signals proceed. Particularly, it is possible to form, as digital ICs, the portions from the comparators 13-1 and 13-2 relating to the tangential push-pull signal and the comparator 10 relating to the total-sum light-quantity signal to the control for the switch 6 for detecting the pit depth or to the switch 6 in the case of configuring the switch 6 as illustrated in Fig. 3, which makes integration thereof easier.

[0057]

Further, in the present embodiment, the differential phase detection method is used to form tracking servo signals, and this differential phase detection method offers the advantage that tracking servo signals are less prone to offsets even if the objective lens for condensing the light beam is significantly displaced and further offers advantages in terms of integration of the circuit since the phase-difference detection can be processed with digital circuits after the binarization of signals from the photo detector.

[0058]

Further, in paying attentions to the photo detector 2, in the present embodiment, the devices are placed to detect the intensity distributions which are substantially parallel with the tangential direction of the pit arrays and the radial direction of the optical disk, out of the reflected light beam. Therefore, it is possible to form any of the tangential push-pull signal, the push-pull signal and the signal corresponding to the total-sum of light quantities, from the outputs from the photo detector, on the basis of the intensity distributions of the reflected light.

[0059]

More specifically, the devices are placed to have substantially "a crisscross-divided square" shape. Such a photo detector having substantially "a crisscross-divided square" shape has been conventionally often used as a light pickup for an optical disk device. Therefore, it is possible to generate focus-error signals with a so-called astigmatism method while concurrently offering the advantage that the polarity of the tracking servo signal can be automatically extracted by detecting the pit depth, according to the present invention, using a conventional light pickup without adding new devices thereto.

[0060]

Further, as already described, for an optical disk having pits with a single depth as conventional optical disks, the polarity of the change of the tangential push-pull signal (b), in association with the level change of the output signal (a) from the adding circuit 4 which can be regarded as the total-sum signal of reflected-light quantities, is constant, which causes the

polarity of the tracking servo signal to be fixed at one appropriate for the pit depth, thus enabling maintaining compatibility with conventional optical disks.

[0061]

Also, for an optical disk of such a recording type that recording marks having different reflectivities, rather than pits, are formed thereon by light irradiation, it is possible to generate tangential push-pull signals as well as total-sum signals of reflected-light quantities. This is because there is generated an intensity-distribution difference between the forward and backward sides along the direction of the light-beam propagation when a light beam is reaching or separating from a recording mark. At this time, the polarity of the tangential push-pull signal is caused by the reflectivity difference between the recording-mark portion and no-recording-mark portion, not by their depths as in the case of pits. Accordingly, the polarity of the tracking servo signal is fixed, thereby normally reproducing information of the recording marks.

[0062]

However, if the content of an optical disk having information associated with the depths of pits is copied onto an optical disk of this recording type, only information of the total sum of reflected-light quantities can be copied, and information of the pit depths can not be copied, thereby preventing the information associated with pit depths from being copied.

[0063]

Also, by utilizing the fact that the polarity of the tracking signal is fixed for an optical disk of the recording type in which recording marks with

different reflectivities are formed, it is possible to adjust pit depths such that the polarity of tracking signals is fixed at the polarity opposite thereto. In this case, while the tracking servo control can be normally performed for an optical disk having information recorded with pits, for an optical disk of the recording type in which information is copied from such an optical disk, the polarity of the tracking servo signal is reversed to cause track deviations, which prevents reproduction of the information therefrom. This is usable as a new measure for copy inhibition.

[0064]

Subsequently, a second embodiment of the present invention will be described using Fig. 3. In the present embodiment, the configuration of the used photo detector for receiving reflected light is different from substantially "a crisscross-divided square shape" as in the aforementioned first embodiment.

[0065]

Generally, photo detectors having substantially "a crisscross-divided square" shape are used in optical pickups formed from combined individual optical components, in many cases. While the description thereof has been omitted in the aforementioned example, such photo detectors having "a crisscross-divided square" shape are also used to create focus servo signals in many cases and, in such cases, an optical technique called an astigmatism method is concurrently utilized.

[0066]

However, this astigmatism method involves sensitive adjustments of the optical system and a great number of individual components, which

tends to increase the assembly/adjustment cost to some extent.

[0067]

On the other hand, in recent years, a photo detector and a semiconductor laser as a light source and the like have been integrated within a single package for reducing the number of individual components and for making the adjustment of the optical system easier and such a package has been widely used. This is a so-called hologram-laser unit in which a portion of the optical system is substituted with a kind of diffraction grating called a hologram and focus servo signals and tracking servo signals can be created and also recorded information signals can be reproduced from outputs of the photo detector incorporated therein.

[0068]

Fig. 3 is a block diagram of main portions when the present invention is applied to an optical disk device using a so-called differential phase detecting method for forming tracking signals, wherein the placement of the devices of a photo detector 22 is not substantially a crisscross-divided square shape and slightly modified therefrom. Further, the designation of the photo detector is changed from that in the previous embodiment.

[0069]

The photo detector 22 in Fig. 3 includes four devices a, b, c and d similarly to that in the first embodiment, and reflected light is divided into fragments by the hologram which is a diffraction grating as aforementioned and these fragments are condensed onto the respective devices. The devices a and b receive the portion of reflected light corresponding to the forward half portion of the light beam along the direction of light-beam

scanning/propagation and the aforementioned hologram is designed such that the quantities of light incident onto both the devices are different from each other depending on the deviation of the focus position with respect to the optical disk, thus enabling providing focus servo signals from the output difference between the devices and b. The devices c and d receive tho portion of reflected light corresponding to the backward half portion and are placed to receive light from the inner side and the outer side of the optical disk, respectively, thus enabling providing tracking signals by these devices c and d through the differential phase detecting method or the push-pull method as will be described later. Further, the total sum of outputs from the all the devices reflect the change in the reflected light quantity, namely the information signals recorded on the optical disk.

[0070]

In order to provide tangential push-pull signals, the light-quantity difference of the reflected light beam along the direction of propagation/scanning, namely the tangential direction of the pit arrays, can be determined as previously described. Therefore, in Fig. 3, the output from the devices a and b which receive reflected light corresponding to the forward half portion is determined by the adding circuit 3-4 while the output from the devices c and d which receive reflected light corresponding to the backward half portion is determined by the adding circuit 3-3, and the difference between both the results of additions is determined by the differential circuit 12.

[0071]

Further, the adding circuit 4 for determining the total-sum signal of

light quantity is connected to determine the total sum of outputs from the four devices a, b, c and d, similarly to in the aforementioned Fig. 1.

[0072]

On the other hand, the adding circuits 3-1 and 3-2 illustrated in the aforementioned Fig. 1 for creating tracking signals by the differential phase detecting method do not exist in Fig. 3. This is because the placement of the devices of the detector 22 is different as previously described and signals usable for the differential phase detecting method can not be provided by using signals from the devices a and b. In other words, tho dovices a and b are devices placed not to detect the intensity distribution along the radial direction of the optical disk, out of the reflected light, while the devices c and d are devices placed to detect it. These differences from the aforementioned photo detector having devices placed in substantially "a crisscross-divided square" shape is due to the fact that the placement thereof is selected such that it is suitable for incorporating the photo detector into a hologram laser unit for making it to be a miniaturized component.

[0073]

When there are outputs from two devices which receive the inner side and the outer side of the reflected light along the radial direction of the optical disk, these outputs exhibit, therebetween, a phase difference corresponding to the relative displacement of the light beam with respect to the pit arrays, thus enabling creating tracking signals by the differential phase detecting method. Consequently, in Fig. 3, the outputs of the devices c and d are directly provided to the comparators 5-1 and 5-2, without being added to other values.

[0074]

The operation and the timings of the circuit of Fig. 3 are the same as those described already in the previous embodiment and thus description thereof is omitted.

[0075]

In paying attentions to the photo detector 22, in the present embodiment, similarly, the devices are placed to detect the intensity distributions of the reflected light along the directions which are substantially parallel with the tangential direction of the pit arrays and the radial direction of the optical disk. (The devices c and d are for detecting the intensity distribution along the direction which is substantially parallel with the radial direction of the optical disk and the pair of devices c and d, in contrast to the pair of devices a and b, detect the intensity distribution along the direction substantially parallel with the tangential direction of the pit arrays). Consequently, similarly to in the aforementioned first embodiment, it is possible to generate any of the tangential push-pull signal, signals required for the differential phase detecting method and signals corresponding to the total sum of the reflected-light quantities, from the outputs from the photo detector.

[0076]

More specifically, the placement of the devices is suitable for a hologram laser unit as previously described and therefore it is possible to offer the advantage that the polarity of tracking servo signals can be automatically extracted by detecting pit depths, according to the present invention, with an optical pickup which is miniaturized using such a

hologram laser unit.

[0077]

Next, a third embodiment according to the present invention will be described using Fig. 4. Although the present embodiment employs a photo detector having devices placed in substantially a crisscross-divided square shape, similarly to in the aforementioned first embodiment, the push-pull method is employed for creating tracking signal, instead of the differential phase detecting method.

[0078]

In Fig. 4, the tangential push-pull signal and the total-sum signal of reflected light quantities are determined and, on the basis thereof, pit depths are detected/determined and only push-pull signals to be used for tracking are extracted, which is identical to that according to the aforementioned first embodiment. The operation thereof is also identical thereto.

[0079]

On the other hand, according to the present embodiment, it is assumed that the push-pull method is used for creating tracking servo signals as previously described. The push-pull method divides reflected light beam into those from the inner side and the outer side of the optical disk and determines the intensity difference therebetween as the tracking servo signal.

[0080]

Therefore, in Fig. 4, the adding circuit 3-1 determines the sum of the outputs from the devices a and b which receive components of reflected light from the inner side of the optical disk while the adding circuit 3-2 determines

the sum of the outputs from the devices c and d which receive components from the outer side of the optical disk, and a differential circuit 17 determines the output-amplitude difference therebetween without through a phase comparing circuit. An LPF 18 extracts low-frequency components from the result of the difference determination and output them as tracking servo signals.

[0081]

The present embodiment employs the push-pull method for creating tracking servo signals and the push-pull method can create tracking servo signals from an optical disk having continuous guiding grooves which mixedly exist thereon, as well as from pit arrays.

[0082]

A forth embodiment of the present invention will be described using Fig. 5. In the present embodiment, similarly to in the second embodiment, it is assumed that a photo detector which is incorporated in a hologram laser unit and has a shape different from a substantially crisscross-divided square shape is used and the push-pull method is used for creating tracking servo signals similarly to in the aforementioned third embodiment. Further, the designations of the respective devices of the photo detector 22 are changed from those of the photo detectors having substantially a crisscross-divided square shape according to the first and third embodiments and are the same as those in the second embodiment.

[0083]

In Fig. 5, the connections and the operations of the portions for determining the tangential push-pull signal and the signals corresponding to

reflected-light quantities and for detecting pit depths, such as the photo detector 22, the adding circuits 3-3 and 3-4 and the adding circuit 4, are similar to those in the aforementioned second embodiment.

[0084]

The difference therefrom is the connections of the devices c and d of the photo detector 22, which are connected to the differential circuit 17 through a switch 6 to determine the output-amplitude difference therebetween.

[0085]

As previously described in the description of the third embodiment, the push-pull method divides the reflected light beam into those from the inner side and the outer side of the optical disk and determines the intensity difference therebetween as the tracking servo signal. On the other hand, as previously described in the description of the second embodiment, the devices c and d receive the portion of reflected light corresponding to the backward half portion and are placed to receive light from the inner side and the outer side of the optical disk. Accordingly, by determining the difference between the outputs of the devices c and d, it is possible to provide tracking servo signals by the push-pull method, similarly to the case of using a photo detector having substantially "a crisscross-divided square" shape.

[0086]

Further, as previously described in the first embodiment, the present invention utilizes the fact that the direction of diffraction of reflected light from a pit and, therefore, the intensity distribution thereof, are varied depending on the depth of the pit and, more specifically, they are reversed at

(λ/4n) as the boundary in assuming that the wavelength of the used light (the light beam directed to the optical disk) is λ and the refractive index of the optical disk substrate is n. This fact is a principle common to any of the embodiments, although it has not been described individually.

[0087]

However, the depth at which the reverse of the direction of diffraction occurs is not limited to (λ/4n) and actually the reverse of the direction of diffraction occurs each time the depth increases from this reference value by (λ/2n). Therefore, generally, in assuming that the light wavelength of the light beam is λ, the refractive index of the optical disk substrate is n and arbitrary numbers are k and m, when the pit depths are classified into any of the groups D1 and D2 satisfying the following conditions, the direction of diffraction of reflected light will be reversed between pits which belong to these groups, thus enabling detection of pit depths and extraction of the polarity of the tracking servo signal.

$$(k\lambda/2n) < D1 < \{(\lambda/4n) + (k\lambda/2n)\}$$

$$\{(k\lambda/4n) + (m\lambda/2n)\} < D2 < \{(m+1) * (\lambda/2n)\}$$

[0088]

Consequently, when there are some reasons in terms of the fabrication of optical disks, for example, when pits having a certain depth are easier to fabricate, it is preferable to select k and m such that such conditions are satisfied. Further, it is not necessary that k and m are the same value, which increases the flexibility in the selection of pit depths.

[0089]

It is generally said that the fabrication thereof is easier and the

quality of reproduced signals is higher when the pit depths are held to a minimum required depth, and therefore, in such a case, it is preferable that at least one of the aforementioned k and m is set to 0.

[0090]

Although when pits are formed to be simple holes, there are the aforementioned limitations on the depths thereof, when holes are formed to have complicated cross sectional areas, there may be two depths which can generate tangential push-pull signals having different polarities, other than the aforementioned depths. Therefore, according to the spirits of the present invention, it is only necessary that the two different depths of pits provided on an optical disk are such that the polarity of the push-pull signal is varied between the pits having different depths.

[0091]

[Effects of the Invention]

According to the present invention, the polarity of the tracking servo signal is automatically extracted by detecting the depths of pits, which enables accurate tracking servo control for optical disks having pits with different depths and also enables extraction of the tracking servo signal from all the pits for optical disks having pits having a single depth, thus maintaining compatibility with conventional optical disks.

[0092]

The detection of the depths of the aforementioned pits is performed on the basis of the light quantity of the reflected light of the light beam directed to the pit array and the intensity distribution difference along the tangential direction of the pit array. These signals can be easily created

from a light pickup and the depths of pits can be distinguished without requiring provision of a new photo detector and sensors.

Brief Description of the Drawings

Fig. 1 is a block diagram illustrating a structure according to a first embodiment of the present invention.

Fig. 2 is a view illustrating signals at respective portions according to the first embodiment of the present invention.

Fig. 3 is a block diagram illustrating a structure according to a second embodiment of the present invention.

Fig. 4 is a block diagram illustrating a structure according to a third embodiment of the present invention.

Fig. 5 is a block diagram illustrating a structure according to a fourth embodiment of the present invention.

Fig. 6 is an explanation view illustrating the principle of the Differential Phase Detection method.

Fig. 7 is an explanation view illustrating the principle of the Push-Pull method.

Fig. 8 is a view illustrating the relationship between the pit depth and the tangential push-pull signal.

[Description of the Reference Numerals]

1	light beam
2	photo detector
3, 4	adding circuits

5, 10, 13 comparators

7 phase comparing circuit

8 LPF

9, 12 differential circuits

11 edge detecting circuit

14 AND gate

15 FF circuit

16 pulse generating circuit

19 S/H-signal generating circuit

20 sample holding circuit

[Title of Document] ABSTRACT

[Abstract]

[Problems]

For an optical disk having pits with different depths, when the pit depth varies, the polarity of the tangential push-pull signal is reversed, and the diffraction pattern of reflected light is varied. Therefore, with the DPD method and the push pull-method which utilize the intensity distribution of reflected light caused by diffraction patterns, the tracking signal may be reversed in the polarity between for deep pits and for shallow pits, which prevents normal tracking servo control with conventional methods such as the differential phase detection method and the push-pull method.

[Means for Solution]

Means for detecting pit depths is provided and the output of the tracking servo signal is controlled, on the basis of signals indicating pit depths, in order to solve the aforementioned problem.

[Selected Figure] Fig. 1